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**SEMI-ANNUAL PROGRESS REPORT**  
**PART III**  
**OSSA PROGRAM**  
**SUPPORTING RESEARCH PROJECTS (U)**  
(JULY 1, 1963 TO JANUARY 1, 1964)

Edited by Harry J. Coons, Jr.  
Research Projects Laboratory

NASA

*George C. Marshall*  
*Space Flight Center,*  
*Huntsville, Alabama*

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TECHNICAL MEMORANDUM X-53069

SEMI-ANNUAL PROGRESS REPORT

PART III

OSSA PROGRAM

SUPPORTING RESEARCH PROJECTS

Harry J. Coons, Jr.

George C. Marshall Space Flight Center  
Huntsville, Alabama

ABSTRACT

This Progress Report presents the OSSA Program of Supporting Research and is Part III of a three part series which describes the George C. Marshall Space Flight Center's Supporting Research Program for the reporting period July 1, 1963 through January 1, 1964.

OSSA tasks are submitted in their respective program areas of Lunar and Planetary ATD, Geophysics and Astronomy, and Meteorological System. Within each program, both in-house and out-of-house tasks convey the purpose, status, accomplishments, problems, and future plans of individual studies with appropriate illustrations. An introductory Summary gives the highlights of the entire report in reduced form. Finally, a brief resume of the professional activities of participating technical supervisors is included in the Appendix.

It should be noted that the Electric Propulsion tasks found in this report should be considered separately from the OSSA program.

Additional copies of this report may be obtained from the MSFC Technical Library, MS-IPL.

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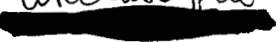
PART III

OSSA PROGRAM

SUPPORTING RESEARCH PROJECTS

(July 1, 1963 to January 1, 1964)

Harry J. Coons, Jr.

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RESEARCH AND DEVELOPMENT OPERATIONS  
RESEARCH PROJECTS LABORATORY



## FOREWORD

The George C. Marshall Space Flight Center's Supporting Research Semi-Annual Progress Report was initiated July 1, 1961 in order to facilitate the exchange and dissemination of technical information and research results by providing a qualitative document for the reference of personnel engaged in the promotion of research activities.

This issue, Part I, Part II, and Part III, presents the status of individual tasks under the cognizance of the Research Projects Laboratory during the period between July 1, 1963 and January 1, 1964. This report does not include the progress of program elements delegated to other specific organizations within MSFC.

This Center is justifiably proud of the effective utilization of research funds as demonstrated by accomplishments such as those found in this issue of the report.

C. G. Miles, Jr., Chief  
Research Survey and Requirements Branch

Ernst Stuhlinger, Director  
Research Projects Laboratory

## ACKNOWLEDGEMENTS

Specific individuals involved in program coordination and report preparation, whose cooperative efforts assisted in the publication of this report include Mr. Edward Burrington, Quality Laboratory; Mr. Ralph Butler and Mr. Clyde Bean, Aero-Astroynamics Laboratory; Mr. Grover Daussman, Astrionics Laboratory; Mr. Jack Bean, Computation Laboratory; Mr. Billy Patton (Tech. illustration), Research Projects Laboratory; Mr. James Holland, Manufacturing Engineering Laboratory; Mr. William Ziak and staff, Management Services Office; Mr. Carl Rieger and Mr. Robert Sanders, Propulsion and Vehicle Engineering Laboratory.

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SEMI-ANNUAL PROGRESS REPORT

PART III

OSSA PROGRAM

SUPPORTING RESEARCH PROJECTS

SUMMARY

This report is concerned with the progress of individual tasks that fall within the scope of the Office of Space Sciences and Applications. Accordingly, tasks are submitted in their respective program areas of Lunar and Planetary ATD, Geophysics and Astronomy, and Meteorological Systems studies.

The abridged and extracted information given in the following introductory summary was worded, re-worded, and drawn from individual task reports, or other material in an attempt to present the more salient features of the various projects as reported during this period.

SECTION I. LUNAR AND PLANETARY PROGRAM

The Marshall Space Flight Center is presently participating in the Lunar and Planetary Program by providing a portion of the research required for the sterilization of planetary space probes. This effort involves the development of materials and sub-systems that will be serviceable and reliable after being sterilized by heat, and other requirements in the development of Mars and Venus landers. More specifically, the Sterilization Program consists of several tasks for the development of sterilizable radomes, potting compounds, and thermo-electric materials; the study of adhesion and cohesion in vacuum; and a task to develop foamed metals for space capsule application. Also, a study of particular importance to this effort is being directed toward the development of guidelines for the design and construction of spacecraft that are to be sterilized.

Sterilization

The design criteria study appears to be moving along satisfactorily toward providing guidelines for the design, manufacture, and to a certain extent, the



sterilization procedure of vehicles that are expected to enter planetary atmospheres. Thermal analysis of an idealized unmanned planetary lander is in progress; joint conductance problems are being considered and typical spacecraft structural materials are being evaluated. Surface finish is also being considered at this time -- Both the "F" values and "D" values are believed to depend to some degree on material surface. Present indications suggest that no specific problems should exist in obtaining equilibrium temperatures of the structure whether in vacuum or an inert conducting gas.

It should be noted that NAS8-5207, "Study of Interface Thermal Contact Conductance," G. E. (funded through the OART Program) is providing information for this study in terms of the many parameters affecting interface conductance.

After thermal analysis, joint and structures study, and materials compatibility investigations, future efforts will consider the entire life of a typical space vehicle structure from subassembly through launch as related to sterilization requirements.

The study to develop and evaluate materials for use in radomes is progressing toward the objective of providing a structural protective covering for spacecraft antennas and its mechanisms. Transmission of the antenna signal with a minimum of distortion and attenuation is a factor of prime consideration. The entire system will be compatible with heat sterilization techniques. During this reporting period, a coating has been developed which may be usable as a thermal reflector, ultra-violet absorber, and a gas impermeable seal.

The study "Development of Improved Heat Sterilizable Potting Compounds" is in the screening phase with a number of different materials being rated. Some results of weight and hardness changes that take place during the heat aging portion of the screening tests are reported. The materials under evaluation include silicones, epoxies and polyesters.

The study to develop improved thermoelectric materials appears to be on schedule and no problems are reported at this time. Several large crystals have been grown and unique equipment for evaluating the thermoelectric properties of these materials after exposure to extreme temperatures and reduced pressure has been designed and fabricated.

The task, "Investigation of Foamed Metals for Application on Space Capsules" is progressing toward the objective of determining the advantages that the foamed metals may have for applications on spacecraft in the form of a capsule shell. Moreover, the mechanical and thermal properties of the foamed

metals are being investigated under this task, along with the continuation of improvement in processes for making foamed nickel, and foamed 316 stainless steel. The major accomplishment during the initial portion of the contract has been the development and standardization of methods for producing nickel and stainless steel foams.

The task, "Study of Adhesion and Cohesion in Vacuum" is developing engineering data for spacecraft designers to insure separation of instrument capsules and other components from spacecraft which have been exposed to a hard vacuum. The study includes design and fabrication of a vacuum test chamber and the evaluation of different combinations of metal couples. Test apparatus has been constructed, resistance heaters for heating test specimen have been manufactured and the study in general appears to be satisfactorily progressing toward the goals of the program.

### Advanced Concepts

Tasks that fall into this area of study are generally concerned with planetary missions using the Saturn Booster with a variety of chemical upper stages. Specifically, these tasks have as their objective, the study and application of methods concerning trajectory calculations.

The task, "Performance and Guidance Trajectory" is developing general perturbation methods for the solution of trajectory optimization problems. Another study, "Optimum Trajectory Study" is performing research in optimization theory and in the stability of motion of nonlinear dynamical systems. These studies appear to be progressing satisfactorily and no unusual problems are reported at this time.

Much useful information as to the character of direct variational methods as applied to trajectory optimization has been generated in the task, "Development of Methods for Trajectory Calculations Using Direct Methods of Calculus of Variation". Specific computational routines have been generated to handle the optimization of two dimensional low thrust and high thrust interplanetary trajectories.

## SECTION II. GEOPHYSICS AND ASTRONOMY PROGRAM

The Geophysics and Astronomy Program consists of two tasks currently being supervised at this Center. The task, "A Study of Kinetics and Rates of

Physical Chemical Reactions of Interest in the Upper Atmosphere" is undertaken to obtain data of use in evaluating the results of the Saturn water release experiments and in predicting the effects of injecting quantities of water into the upper atmosphere. The task, "Measurement of Ionospheric Electron Content" is underway in preparation for receiving, recording, and analyzing signals from the Ionosphere Beacon Satellite (S-66), and other related measurements.

### Space Chemistry

In the study of the Kinetics of physico-chemical reactions of interest in the upper atmosphere, emphasis is placed upon the photo-chemical dissociation of atmospheric constituents and on the effect of water vapor upon these constituents. Studies pertain to the photo-dissociation of water by ultra-violet radiation at low pressures; plans call for the detection and determination of the various atomic, molecular and ionic species produced. It should be noted that the major portion of the first phase of this task involves the acquisition and development of suitable equipment.

### Ionospheric and Radio Physics

The task concerning the measurement of ionospheric electron content has the objective of measuring the number of electrons per square meter in the ionosphere below satellite 1959 Iota, Explorer VII, and below the ionosphere beacon satellite "S-66". These measurements are to be correlated with solar and other geophysical measurements. During this reporting period, progress has been limited to preparations for receiving, recording, and analyzing S-66 signals, and to preliminary work with some available data from Explorer VII.

## SECTION III. METEOROLOGICAL PROGRAM

The task, "High Altitude Wind Shear Measuring Program" constitutes this Center's only study in the Meteorological Program during the reporting period. This study is a follow-up on the HOPI-DART program and is oriented toward putting the system to operational use.

### Meteorological Systems Research

The objective of the "Wind Shear" study is to use a rocket system (chaff tracked by radar) to obtain wind shear measurements, especially in the 70 to 90 km altitude region for analysis of atmospheric conditions at Cape Kennedy, Florida.

This data is being acquired for use in design studies for large space vehicles. During this reporting period fourteen flights were made in which six met specifications. Plans call for the firing of additional rockets at the rate of one per week for a year's time to collect statistical sample of data for design criteria studies.

#### SECTION IV. ELECTRICAL PROPULSION

(NOTE: This section should be considered separately from the OSSA Program.)

Studies in this section of the report are concerned with plasma dynamics, electron wave functions, and the vapor pressure of cesium.

The study, "computer solutions of the Vlasov Equations" reports the near completion of a computer program which permits solutions of plasma diode potential distribution problems. Also, some potential distribution curves for planar and cylindrical plasma diodes have been obtained. Future plans call for the continued development of the cylindrical diode program and the investigation of various classes of solutions to cylindrical and planar diode problems.

The study to calculate electronic wave functions by Hartree method expired during this period of the report. A general review report was written covering the problems encountered and possible approaches in solving them. It should be noted that the latest results were published in Physical Review, Vol. 130, April 15, 1963. Work was also completed on the study to determine the vapor pressure of cesium. Difficulties in obtaining suitable equipment prevented the determination of vapor pressure over the range of 0 to 600°C; however pressures were determined between 150°C and 215°C.

#### APPENDIX

A brief resume of the professional activities of participating technical supervisors is included in this part of the report.

## SECTION I. LUNAR AND PLANETARY PROGRAM

(Sterilization)

### A. A STUDY OF DESIGN GUIDELINES FOR STERILIZATION OF SPACECRAFT

Submitted by  
(Technical Supervisor)

Ron G. Crawford  
R-P&VE-SAA, 534-8023

#### 1. Project Data

Contract number: NAS8-11107, -20-63

Completion date: 5-20-64

Contractor: General Electric Company  
Missile and Space Division  
Spacecraft Department,  
Philadelphia 1, Pennsylvania

2. Purpose of Project. The purpose of this study is to establish guidelines for the design, manufacture, and sterilization of vehicles that are expected to enter planetary atmospheres.

3. Technical Status. Very little technical data was available on this subject prior to this study. While some conclusions are available as a result of the first three months of this study, it is generally agreed that the surface has only been scratched and that considerable work must be done in this field in the remaining months of this study and in follow-on studies.

The present sterilization procedure requires heating the complete landing capsule and enclosing biological barrier to an equilibrium temperature of 135°C and maintaining this temperature for 24 hours. These numbers are minimum requirements and this study will investigate up to 150°C equilibrium temperature for up to 60 hours.

The effect this process has on the structure is detrimental for many typical designs and materials. Improved design concepts are currently being

developed. Preference is being given to those concepts which can be cycled between equilibrium temperatures of 150°C and 25°C without warping or other adverse deflections. Systems which allow a fast heating and cooling rate are also desirable. Some preference is being given to those concepts which do not entrap dead microorganisms.

4. Major Accomplishments. A thermal analysis has indicated that a typical aluminum structure can be brought up to equilibrium temperature in a vacuum within a few hours. This indicates that no specific problem in obtaining equilibrium temperature is expected whether the structure is in a vacuum or in an inert conducting gas.

The following general order of structural joint desirability, based on thermal conductance, has been established.

- |                 |                  |
|-----------------|------------------|
| Most desirable  | 1. Fusion welded |
|                 | 2. Brazed        |
|                 | 3. Bonded        |
|                 | 4. Bolted        |
|                 | 5. Seam welded   |
|                 | 6. Spot welded   |
| Least desirable | 7. Riveted       |

5. Problems. No difficult problems are now apparent and the objective of this task should be obtained on schedule.

6. Future Plans. In the near future, thermal analysis of an assumed model in a conducting inert gas atmosphere will be performed and the advisability of using dry nitrogen determined. Structural joints for possible use in sterilized structures will be developed and evaluated. This work will lead to some firm conclusions on types of joints to be avoided and those most highly recommended. The effect of the sterilization process on detail structural components, such as columns, rings and stiffeners, will be determined. The compatibility of materials and material combinations with the sterilization requirements will be determined. The effect of surface finish will be determined and recommendations made accordingly.

Finally, in future studies, the entire life of a typical space vehicle structures from subassembly through launch will be considered in light of the sterilization requirement. Trade-off studies involving complete sterilized packages, including the enclosing container and its support structure, will be performed. Firm recommendations to guide future structural designs will be developed.

7. Illustrations. None.

B. DEVELOPMENT OF DIELECTRIC WINDOWS/PROTECTIVE COVER  
MATERIALS FOR SPACECRAFT ANTENNAS

Submitted by  
(Technical Supervisor)

E. C. McKannan  
R-P&VE-ME, 876-6622

1. Project Data

Contract number: NAS8-11026, 6-27-63

Completion date: 6-27-64

Contractor: Hughes Aircraft Company  
Culver City, California

2. Purpose of Project. This contract provides for the development and evaluation of materials for use in radomes and antenna covers on spacecraft. The cover must protect and seal the antenna and its associated mechanisms and distortion to the antenna signal. Therefore, the materials must have low dielectric loss properties, high mechanical strength and rigidity, high temperature resistance for sterilization, launch, and planetary atmospheric environments, low gas permeability, and resistance to the effects of the space environment. Since no single material is expected to provide all these requirements, compromises, composites, laminates, and coatings will be studied.

3. Technical Status. Several candidate materials have been received from commercial vendors or prepared by the contractor, and some of the more critical properties have been determined. The polymers of most interest are polyimides and polybenzamidazoles, in addition to the more common reinforced silicones and polyesters. Quartz and alumina also present strong possibilities. As a protection for the polymers, a coating has been employed which simultaneously functions as a thermally controlled reflector, ultra-violet absorber, and sealant for gas permeability. Initial evaluation of this coating indicates only a small effect on dielectric properties. Also, because the reinforcing glass may be a major fraction of the volume of material, low loss glass fibers will be evaluated.

4. Major Accomplishments. A coating has been developed which, when applied to the polymer candidate window materials, simultaneously functions as a thermal reflector, ultra-violet absorber, and a gas impermeable seal. Some of the more critical properties have been determined for several candidate materials.

5. Problems. None.

6. Future Plans. Testing will continue on candidate materials to determine critical electrical and physical properties.

7. Illustrations. None.

C. DEVELOPMENT OF AN IMPROVED HEAT STERILIZABLE POTTING COMPOUND

Submitted by  
(Technical Supervisor)

John T. Schell  
R-P&VE-MNR, 876-8572

1. Project Data

Contract number: NAS8-5499, 6-29-63

Completion date: 6-30-64

Contractor: Materials Technology Department  
Components and Materials Laboratory  
Hughes Aircraft Company,  
Culver City, California

2. Purpose of Project. This contract is directed toward the development of at least one transparent potting compound suitable for use on printed circuit boards and for embedding electronic modules. This material must be capable of withstanding continuous exposure to a temperature of 200°C (392°F) for a twenty-four hour period without loss of physical or electrical properties. Additionally, the product must be compatible with all parameters of the space environment. Specific requirements for the desired potting compound are as follows:



- a. Hardness: maximum Shore A of 60 to 70° F (21° C)
- b. Strength: minimum tensile strength of fifteen hundred pounds per square inch per ASTM D-412-51T.
- c. Adhesive Characteristics: The material shall demonstrate adhesive characteristics to substrates used commonly in electronic sub-assemblies.
- d. Compression Set: No formal requirement is established, but compression set shall be held to a minimum.
- e. Moisture Absorption: Moisture absorption after immersion for twenty-four hours at 100° C (212° F) shall not exceed 0.196 percent.
- f. Thermal Properties: The potting compounds shall have the highest practical specific heat and thermal conductivity.
- g. Thermal Expansion: The desired linear coefficient of thermal expansion is of the order of  $10 \times 10^{-6}$  inch per degree centigrade.
- h. Electrical Properties per MIL-S-8516C: dielectric constant -- maximum of 4; dielectric strength -- three hundred fifty to four hundred volts per mil; minimum volume resistivity --  $10^{-6}$  ohm-centimeters at 70° F (21° C) and  $10^{13}$  ohm-centimeters at 150° F (66° C); minimum surface resistivity --  $10^{12}$  ohms per square centimeter; minimum insulation resistance --  $10^5$  meg-ohms.

3. Technical Status. Several samples of materials potentially suitable for specified applications have been received and are being rated currently by a preliminary screening process. When variations in cure schedules and cross-linking agents are taken into account, approximately thirty samples of materials are being tested. The materials being evaluated are silicones, epoxies, and polyesters. No supplier has been willing to recommend a polyurethane for the temperature service required.

Past experience by the contractor has indicated that molecular distillations at low absolute pressures improve the resistance of materials to the space environment. A magnetic clutch drive for a molecular still has been designed for use in this program to modify the materials which show the best results in the preliminary screening and evaluation tests which are now being initiated.

4. Major Accomplishments. The major accomplishments under this contract have been confined to a definition of the methods necessary to formulate and evaluate encapsulation materials. A screening program of state of the art materials has been initiated in an effort to detect candidate polymer systems for future modification.

5. Problems. No significant problems have been encountered in the contract work to date.

6. Future Plans. Future work under this contract will proceed according to the Scope of Work. Candidate polymer systems which survive the initial screening tests will be subjected to more rigorous mechanical, physical and electrical testing. Chemical and physical modifications of the more promising polymers may be initiated in order to optimize critical properties.

7. Illustrations. None.

D. DEVELOPMENT OF IMPROVED THERMOELECTRIC MATERIALS  
FOR SPACECRAFT APPLICATIONS

Submitted by  
(Technical Supervisor)

R. L. Gause  
R-P&VE-ME, 876-4589

1. Project Data

Contract number: NAS8-11075, 6-29-63

Completion date: 7-29-64

Contractor: Tecumseh Products Company  
Ohio Semiconductor Division  
Columbus, Ohio

2. Purpose of Project. This contract provides for developmental and qualification testing of improved thermoelectric materials of potential use as cooling devices for spacecraft components. Specifically, the contractor is directed to develop thermoelectric materials which have a figure-of-merit greater than  $4.0 \times 10^{-3}$  per degree centigrade at  $25^{\circ}\text{C}$  ( $77^{\circ}\text{F}$ ) and which are capable of continuous operation at temperatures from  $-250^{\circ}\text{C}$  ( $-418^{\circ}\text{F}$ ) to  $300^{\circ}\text{C}$  ( $572^{\circ}\text{F}$ ) and

at an environmental pressure of  $1 \times 10^{-8}$  millimeters of mercury. The program provides for an initial theoretical investigation to establish the most appropriate approach for developing materials with the specified high figure-of-merit. In this initial study, consideration will be given to such concepts as (1) varying the solid solution concentration of binaries with or without doping agents, (2) selecting new matrices, new doping agents, and new solid state solution alloys, (3) determining the preferential orientation of anisotropic materials, and (4) modifying lattice structures and interatomic spacing. Based upon the results of this initial study, new thermoelectric materials will be developed and identified according to chemical composition and lattice structure, and pertinent thermoelectric properties will be determined at various differential temperatures across the specimen and at widely varying environmental temperatures. These materials which, on the basis of these tests, demonstrate suitable physical properties and high figures-of-merit shall be formed into couples and tested in air and at reduced pressure to determine the coefficient of performance (defined as the rate of heat removal from the cold junction divided by the electrical power input to the couple). Finally, the contractor shall fabricate and demonstrate thermoelectric cooling modules of components involving eight couples electrically in series.

3. Technical Status. The contractor has successfully grown large, single crystals of bismuth which superficially appeared to be free of striations. The crystals were obtained by the controlled atmosphere, RF Heating, quick-freeze, growth method after several other methods had been tried. Both horizontal zone crystallization and vertical Bridgman Casting Techniques were tried on Ag-Sb-Te type alloys. The vertical casting technique was successfully used to produce 5 and 7 mm diameter rods of homogeneous  $\text{AgSbTe}_2$ ,  $\text{Ag}_{19}\text{Sb}_{29}\text{Te}_{52}$ ,  $\text{AgBiTe}_2$ , and  $\text{Ag}_{19}\text{Bi}_{29}\text{Te}_{52}$  alloys. The AgSbTe alloys were n-type at room temperature. In view of these results, the vertical casting technique was selected as the method to use in conducting the exploratory studies for the Ag-Sb-Te system. The equipment for measuring the electric, thermoelectric, and thermomagnetic properties of materials from  $-190^\circ\text{C}$  to  $+300^\circ\text{C}$  at a pressure of  $<1 \times 10^{-7}$  mm Hg has been completed and is being checked out.

4. Major Accomplishments. Large single crystals of bismuth superficially free of striations have been successfully grown. In addition, several Ag-Sb-Te alloy crystals of large dimensions were produced. Unique equipment for evaluating the thermoelectric properties of these materials at extreme temperatures and reduced pressure was designed and fabricated.

5. Problems. None.

6. Future Plans. Property measurements will be made on Bismuth and AgSbTe materials to determine their efficiency for thermoelectric applications. Investigations to improve the methods for growing of high purity crystals will continue.

7. Illustrations. None.

E. INVESTIGATION OF FOAMED METALS FOR APPLICATION ON SPACE CAPSULES

Submitted by  
(Technical Supervisor)

H. H. Kranzlein  
R-P&VE-MMP, 876-2467

1. Project Data

Contract number: NAS8-11048, 6-29-63

Completion date: 9-29-64

Contractor: Ipsen Industries, Inc.

2. Purpose of Project. The objective of this contract is to develop and evaluate ductile metal foam for possible application in space capsules. During the first six months the contractor's effort has been devoted to the development of nickel, 316 stainless steel, and aluminum alloy foams. The basic process to be used to produce foamed metals involves foaming a slurry of fine metal powders followed by drying and sintering.

3. Technical Status. The contractor has demonstrated that nickel foams can be produced with densities as low as 15 per cent of theoretical, although at present it appears that densities of approximately 20 per cent of theoretical are required before the foams exhibit any appreciable ductility. The procedures for producing foamed nickel have been established and standardized. A dewaxing and two sintering stages are required to produce foamed nickel. The dewaxing operation is used to drive off most of the organic binders introduced during foaming of the slurry. The first sintering stage, conducted in nitrogen and vacuum atmospheres, is used to complete removal of organic materials and initiate metallic bonding. The second sintering stage is carried out in a hydrogen atmosphere.

The hydrogen reduces all oxides on the nickel and assures metal to metal bonding. Samples are being prepared for physical and mechanical property tests.

The development of stainless steel foams has closely paralleled that of the nickel foams. The conditions necessary to produce good foams of 316 stainless steel are similar to those used in foaming nickel. However, the greater stability of the chromium oxide necessitates some changes in the final sintering step to assure complete metal-to-metal bonding. As in the case of nickel foam, the procedures for producing 316 stainless steel foams have been established.

Development of aluminum alloy foams has not progressed as well as the development of nickel and stainless steel foams. Three aluminum alloys, 1100, 7075, and 7178 are being used in the development program. High quality foams of these alloys have not been prepared. This is due to the difficulty encountered in reducing the aluminum oxide which coats the aluminum powders. Without reduction of these oxides it is impossible to obtain metal-to-metal bonding during sintering. Methods for reducing the aluminum oxide are being investigated. These include additions of fluxes to the powder slurry, halide reduction, and hydride additions to the slurry.

4. Major Accomplishments. The major accomplishment during the initial portion of the contract has been the development and standardization of methods for producing nickel and stainless steel foams.

5. Problems. Development of ductile aluminum foams has proven to be a greater problem than anticipated. Failure to find methods for reducing the aluminum oxide which coats the aluminum powders has made it impossible to obtain the metal-to-metal bonding required for the production of ductile foams.

6. Future Plans. During the final phase of the present contract, three additional alloys will be foamed. Final selection of the three alloys has not been made. Mechanical and physical properties of the six foamed metals will be determined. Also joining and bonding characteristics will be evaluated using two foamed metals. Sandwich structures will be formed by both brazing and adhesive bonding.

7. Illustrations. None.

## F. INVESTIGATION OF ADHESION AND COHESION IN VACUUM

Submitted by  
(Technical Supervisor)

K. E. Demorest  
R-P&VE-ME, 876-4241

### 1. Project Data

Contract number: NAS8-11066, 6-29-63

Completion date: 6-29-64

Contractor: Hughes Aircraft Company  
Culver City, California

2. Purpose of Project. The purpose of this project is to determine the conditions at which adhesion or cohesion of structural metals occur. The data obtained shall be presented in a way which will be useful to spacecraft designers in determining the requirements for separation of components after they are subjected to high temperatures and low environmental pressures resulting from prelaunch testing and sterilization procedures and from exposure to the space environment.

The contractor is directed to provide one or more devices capable of (1) providing and measuring a wide range of tensile and compressive forces from 0 to 100,000 psi for contacting and separating test specimens, (2) providing a wide range of specimen temperatures from 25°C to 500°C, and (3) providing a minimum environmental pressure not greater than  $5 \times 10^{-9}$  millimeter of mercury without oil contamination.

The materials tested in various contacting couples shall include but not be limited to the following:

- a. a stainless steel of the 300 series
- b. an aluminum alloy, such as 2014-T6
- c. a high nickel, superalloy, such as Waspaloy or Rene' 41
- d. a precipitation hardened stainless steel, such as A-286
- e. a titanium alloy, such as 6A1-4V-Ti.

3. Technical Status. The test equipment for use at  $10^{-9}$  millimeter of mercury,  $25^{\circ}\text{C}$  to  $500^{\circ}\text{C}$ , and 0 to 100,000 psi compressive load, has been designed and is almost complete. Proof testing of the equipment will be done using copper/copper couples since adhesion or cohesion should be induced with relative ease in the material.

4. Major Accomplishments. The necessary test equipment for adhesion-cohesion testing of materials at an environmental pressure of  $10^{-9}$  millimeter of mercury and temperatures to  $500^{\circ}\text{C}$  has been designed and fabrication has been initiated.

5. Problems. None.

6. Future Plans. The previously mentioned test equipment will be used to evaluate specific metals for cohesion-adhesion properties at elevated temperatures and reduced pressures.

7. Illustrations. None.

#### ADVANCED CONCEPTS

##### A. PERFORMANCE AND GUIDANCE TRAJECTORY

Submitted by  
(Technical Supervisor)

W. E. Miner  
R-AERO-G, 876-3997

##### 1. Project Data

Contract number: NAS8-11099, 9-19-63

Completion date: 9-18-64

Contractor: United Aircraft Corporation  
Research Laboratories  
East Hartford 8, Connecticut

2. Purpose of Project. To develop general perturbation methods for the solution of trajectory optimization problems.

3. Technical Status. Initial investigations are being made toward obtaining analytic solutions for optimum power-limited interplanetary trajectories. Solutions to the linearized circle to circle transfer problems have been obtained in rotating rectangular and spherical coordinates, and in Lagranges' planetary variables. The latter solution also holds for initial and final orbits of small eccentricity. The synthesis of the optimal controls has been obtained in all three coordinate systems and expressed in terms of the current state and time to go. Attempts to derive approximations that will represent fuel consumption outside the range of validity of the linearized approximations have been made, but have met with limited success. Approximations to the non-linear power-limited and constant thrust problems are also being studied.

4. Major Accomplishments. See Technical Status. The major accomplishments expected from this study are the determinations as to whether the general perturbation approaches to the analytical solution of trajectory optimization problems being followed are promising or not. The analytical results of the study will be published and available in future reports in the "Progress Reports on Studies in the Fields of Space Flight and Guidance Theory" series.

5. Problems. No unusual problems encountered this reporting period.

6. Future Plans. Work will continue on both the linearized analysis and on non-linear approximations. Plans to find such solutions as will form a suitable basis for a general perturbations solution to the true trajectory optimization problem.

7. Illustrations. None.

B. DEVELOPMENT OF METHODS FOR TRAJECTORY CALCULATIONS  
USING DIRECT METHODS OF CALCULUS OF VARIATION

W. E. Miner  
R-AERO-G, 876-3997

1. Project Data

Contract number: NAS8-1549, 3-28-61

Completion date: 3-28-62  
Extended to 3-28-63  
Extended to 3-28-64



Contractor: Grumman Aircraft Corporation  
Research Department  
Bethpage, New York

2. Purpose of Project. Apply direct methods of calculus of variations to trajectory calculations with special attention to low thrust trajectories.

3. Technical Status. Computational procedures are being developed for determining optimal, three dimensional, low thrust interplanetary trajectories by a successive approximation technique of the direct variational calculus. Procedures for constant and variable thrust have been completed and checked out. Evaluations are continuing for applications in the very low and high thrust areas. Investigations have also been made toward iterative solutions of the nonlinear two point boundary value problem associated with the indirect variational calculus, by means of a sequence of linear boundary value problem solutions.

4. Major Accomplishments. Much useful information as to the character of direct variational methods as applied to trajectory optimization has been generated. Specific computational routines have been generated to handle the optimization of two dimensional low thrust and high thrust interplanetary trajectories. Some of the problems inherent to the computation of very-low thrust trajectories have been studied. A very promising method of solving two point boundary value problems associated with indirect variational methods has been suggested.

5. Problems. No unusual problems have occurred in this area.

6. Future Plans. Developments and evaluations will continue.

7. Illustrations. Progress Report No. 5 on "Studies in the Fields of Space Flight and Guidance Theory" is available.

#### C. OPTIMUM TRAJECTORY

Submitted by  
(Technical Supervisor)

C. C. Dearman  
R-AERO-G, 876-4033

1. Project Data

Contract number: NAS8-11020, 6-29-63

Completion date: 7-28-64

Contractor: Martin-Marietta Corporation  
Denver Division  
Denver 1, Colorado

2. Purpose of Project. In general, the purpose of this project is to perform research in optimization theory and in the stability of motion of nonlinear dynamical systems.

In particular, the purpose is to study the relations between Liapunov's second method and the optimization of guidance functions for space vehicles subject to thrust and gravitational forces. The purpose of this research is to ensure that the dynamical system with optimal guidance is stable in a practical sense. As an integral part of this research, investigations should also be made in the determination of the domain of stability, i.e., the set of all initial values from which the system's motion may originate and satisfy the chosen stability criteria.

3. Technical Status. Feasibility studies have begun on applications of Liapunov's second method and the optimization of guidance functions for space vehicles subject to thrust and gravitational forces. In particular, studies are being carried out on the Hamilton-Jacobi equations associated with guidance problems.

4. Major Accomplishments. None have been reported during the period covered herein.

5. Problems. See Technical Status.

6. Future Plans. See Technical Status.

7. Illustrations. None.

## SECTION II. GEOPHYSICS AND ASTRONOMY PROGRAM

### SPACE CHEMISTRY

#### A. A STUDY OF KINETICS AND RATES OF PHYSICAL CHEMICAL REACTIONS OF INTEREST IN THE UPPER ATMOSPHERE

Submitted by  
(Technical Supervisor)

Dr. Spencer G. Frary  
R-RP-N, 876-8036

##### 1. Project Data

Contract Number: Not Applicable

Contractor: MSFC In-House

2. Purpose of Project. To study the reaction kinetics of physico-chemical reactions of interest in the upper atmosphere. Emphasis will be placed upon the photo-chemical dissociation of atmospheric constituents and on the effect of water vapor upon these constituents. Attempts to evaluate the results of the High Water experiments in which large quantities of water were released at the apex of the Saturn's trajectory (about 160 km) indicated the lack of experimental data in this field. The Planetary Atmospheres Subcommittee of the Space Sciences Steering Committee has also stressed the need for such data in their various Planning documents. A program was therefore stated which it was hoped would answer some of the questions brought out by the High Water experiments as well as fit in with that recommended by the Planetary Atmospheres Subcommittee.

3. Technical Status. Equipment has been obtained for preliminary studies of the photo-dissociation of water vapor by Ultra-Violet radiation at low pressures. Equipment for further studies involving the more precise and accurate detection and determination of the various atomic, molecular and ionic species produced is now being ordered.

The program, as planned for the present, is a study the photo-dissociation of water under the effects of extremely low pressure and intense solar radiation and the reactions of these products of this dissociation with some of the atomic, molecular and ionic species to be found in the upper atmosphere. The various

species to be studied would include:

$N_2$ , N,  $N_2$ , NO,  $NO_2$ ,  $O_2$ , O, O,  $O_2$ ,  $O_3$ , O, OH, OH,  $H_2$ , and H

Studies of these would involve not only the measurement of cross-sections and reaction rates but might include purification and determination of purity of some of these materials by chemical or physical means.

Spectral analysis of radiation emitted during these reactions is essential in the over-all program. However, for the present, it is proposed to concentrate on the detection of atomic and ionic (particle) reactants. A vacuum ultra-violet scanning monochromator and spectrometer, now on order for use in the detection of free radicals by spectral absorption techniques, can be used for spectral analysis of emitted radiation and determination of atomic and molecular spectra in later phases of the program.

Experimental Techniques: A literature survey of the subject and discussions with persons engaged in similar and related work indicated the feasibility of using molecular beams, or crossed beams, for the determination radiation effects, reactions with other substances and the measurement of cross sections. Reaction products are to be detected and measured with a mass spectrometer or by spectral absorption using a vacuum ultra-violet spectrometer.

Water vapor is decomposed by H and OH by radiation shorter than 2400 Å with the most effective wavelengths below 1800 Å. This is in the near vacuum ultra-violet region of the spectrum. Strong absorption by air makes it necessary that all optical components be placed in a vacuum. All optical components, windows, lenses and prisms, must be of quartz, usually of a special grade, or, for the lower wavelengths, of calcium or lithium fluoride. The apparatus was therefore designed with these requirements in mind.

Apparatus and Equipment, Reaction Chamber: The reaction chamber is fabricated from nominal 8-in. (20 cm) stainless steel tubing fitted with 150 lb flanges. Viton O-rings are used for vacuum tight connections. This chamber is in two sections, differentially pumped by 4 and 6-inch oil diffusion pumps respectively. The first contains the collimating assembly for producing a molecular beam of the substance to be studied, probably water vapor in the first experiments. The second section, separated by a metal plate with a small centrally located orifice through which the beams pass, in which the material will be subjected to the radiation also contains electrically charged collector plates for determination of ions or electrons produced by the reaction. In the first experiments a residual gas analyzer (a small cycloidal mass spectrograph) will be used to determine the masses of

the particles produced. A Time-of-Flight mass spectrometer is to be used in later experiments.

Radiation Sources: In the first experiments external ultra-violet lamps are to be used, with quartz windows in the chamber, to admit the radiation. These, obtained from the Hanovia Lamp Co. are of limited intensity and operate in the upper wave-length region. For higher intensities at lower wavelengths a flash photolysis apparatus is to be used. A capacitor bank, capable of delivering 24,000 joules at 20 kilovolts, is being designed and will be fabricated with the assistance of the Manufacturing Engineering Laboratory. This will energize a helically shaped flash lamp to be placed inside the reaction chamber.

Spectral Absorbtion Apparatus: A One Meter 15° Focusing Normal Incidence Vacuum Scanning Spectrometer is on order to study free radicals and other intermediates produced in the reactions by spectral absorbtion methods but delivery is not expected for from six to nine months.

Mass Spectrometer: A Bendix Time of Flight Mass spectrometer is also on order but delivery is not expected for about a year.

Present Status of the Program. Equipment purchased from Fy-63 funds has been received and is being assembled. This assembly and testing of the present equipment will probably occupy the remainder of FY-64.

4. Major Accomplishments. See Technical Status.

5. Problems. No major problems are reported at this time.

6. Future Plans. Experiments with this equipment will probably occupy the better part of the first quarter of FY-65. The second and third quarters will be required for assembly and testing of the high intensity spectral sources and the ultra-violet spectrometer. Work with the Time of Flight Mass Spectrometer will probably not get under way until late in FY-65 or early in FY-66.

The equipment now on hand is to be assembled and preliminary observations made. A flash photolysis apparatus to give more intense radiation at wave lengths below 2000 Å is being assembled with the assistance of Mr. Schwinghamer's group in the Manufacturing and Engineering Laboratory. A capacitor bank, capable of delivering 48,000 joules at 20,000 volts, will energize a helically shaped flash lamp to be placed inside the reaction chamber. Reaction rates and products will be studied by absorbtion techniques using a vacuum ultra-violet scanning spectrometer, and by a time-of-flight mass spectrometer.

Future funding: The equipment now on order should provide most of the major items needed for this year (FY-1964). However, it is difficult to anticipate, this far in advance, future needs. Replacement parts, supplies and minor items will certainly be needed. Change in emphasis in the program may necessitate some additional apparatus and equipment not on hand or readily available.

7. Illustrations. See figures 1, 2, 3.

## IONOSPHERIC AND RADIO PHYSICS

### A. MEASUREMENT OF IONOSPHERIC ELECTRON CONTENT

Submitted by  
(Technical Supervisor)

Dr. E. A. Mechtly  
R-RP-P

1. Project Data

Contract number: GO No. H-54704

Contractor: MSFC In-House and  
Alabama A&M College  
Normal, Alabama

2. Purpose of Project. To measure the number of electrons per square meter in the Ionosphere below Satellite 1959 Iota (Explorer VII) and below the Ionosphere Beacon Satellite (S-66). To correlate these measurements with solar and other geophysical measurements.

The operation of the Ionosphere Beacon Satellite (S-66) is required for the performance of this research task. S-66 has not yet been launched into orbit. Therefore, progress has been limited to preparations for receiving, recording, and analyzing S-66 signals; and to preliminary work with some available data from Explorer VII.

3. Technical Status. One of the Avco-Crosley ionosphere beacon satellite, is installed in Green Mountain, southeast of Huntsville, Ala., in a building maintained by the MSFC Astrionics Laboratory as a receiving station for telemetry signals from Saturn launch vehicles. T. A. Barr, J. G. Gregory, W. H. Edens, and other personnel of the Astrionics Laboratory have cooperated

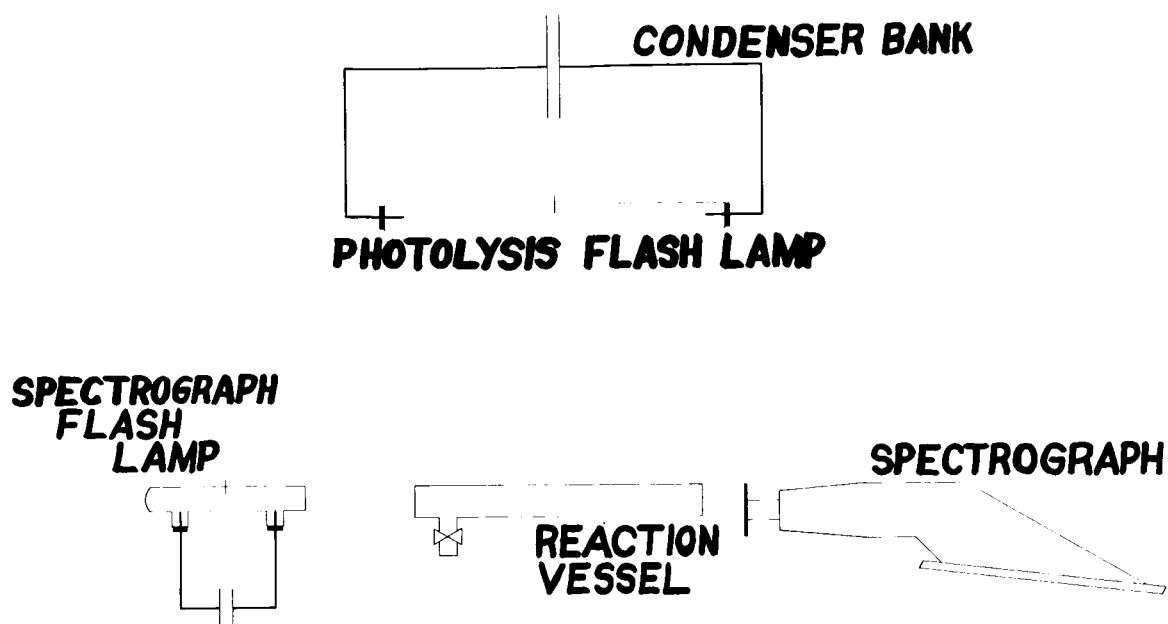


FIGURE 1. A FLASH PHOTOLYSIS APPARATUS

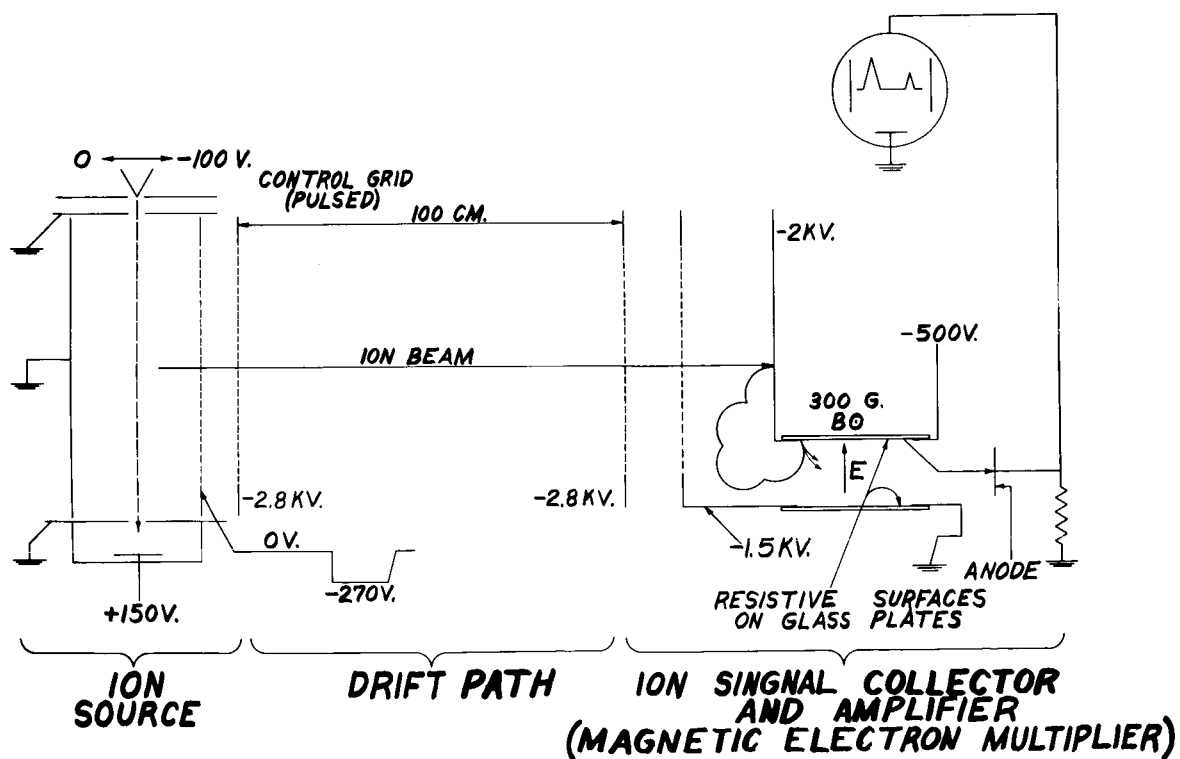


FIGURE 2. SCHEMATIC OF BENDIX TIME-OF-FLIGHT MASS SPECTROMETER

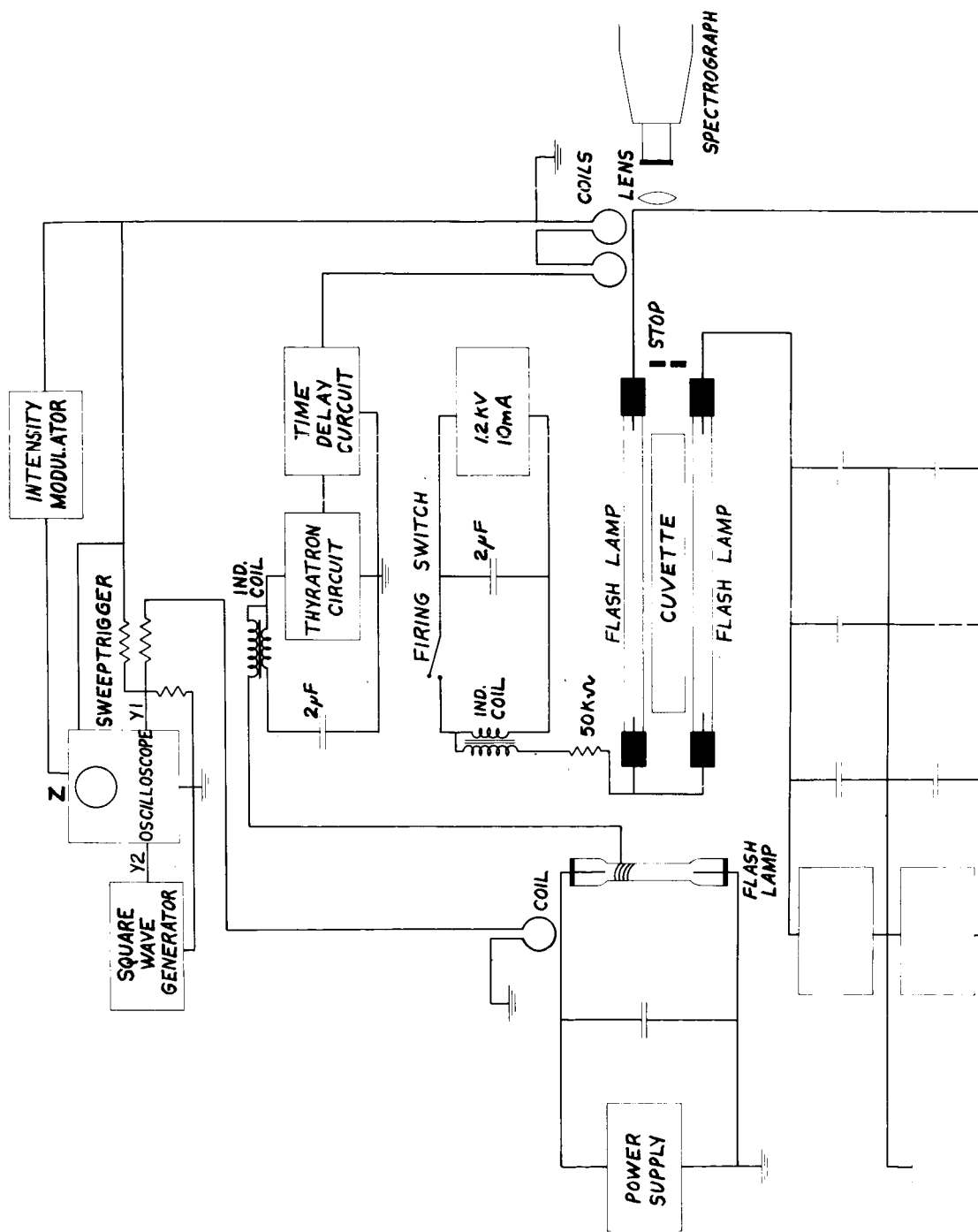


FIGURE 3. A FLASH PHOTOLYSIS APPARATUS



with E. A. Mechtly of the Research Projects Laboratory in preparing the Avco-Crosley receiver for use with S-66. Astrionics Laboratory personnel are prepared to operate the receiver, and to record polarization and dispersive doppler data when S-66 is orbited.

Ampex and Sanborn recording equipment is presently provided by the Astrionics Laboratory. However, this equipment will not be available for recording S-66 signals during preparations for and conduct of Saturn launches. To prevent the loss of data during Saturn operations, additional recording equipment has been ordered. As a back-up for the Avco-Crosley receiver, a pair of the Magnavox Model B receivers, designed by G. W. Swenson, have been ordered.

F. A. Rodrigue and other personnel of the Computation Laboratory have cooperated with E. A. Mechtly in preparing data processing and analysis programs for the anticipated S-66 data, and less sophisticated programs for the simple single frequency data available from Explorer VII.

Students of the Alabama Agricultural and Mechanical College (in Huntsville) have assisted in digitizing the 20 MHz Faraday polarization fading data available from Explorer VII under an OMSF FY 1963 funded contract. This work was completed on January 12, 1964. A copy of the A&M College Technical Summary Report, and a copy of an analysis of part of the Explorer VII data titled "Comparison of Winter Ionosphere Electron Contents Observed at Boulder, Stanford, Urbana, and Huntsville" are attached (Attachment I and II).

A tabulation follows on funds expended or committed in support of this research task:

C = committed	O = obligated	E = expended
<u>Date</u>	<u>Order No.</u>	<u>Dollars</u>
<u>Discription</u>		
E Aug 30, 1963	H-55371	325.00 (MSFC Operating Funds)
E Sep 24, 1963	NAS8-8611	3482.00 (OSS)
E Sep 27, 1963	H-56262	1357.00 (OMSF)
E Oct 9, 1963	H-54704	1000.00 (OMSF)
C Nov 14, 1963	CPB 11-0200-64	1000.00 (OSS)

C = Committed

O = obligated

E = expended

<u>Date</u>	<u>Order No.</u>	<u>Dollars</u>	<u>Description</u>
C Jan 3, 1964	CPB 11-4032-64	6675.00 (OSS)	Sanborn Recorder
C Jan 3, 1964	CPB 11-4033-64	18,460.00 (OSS)	Ampex Recorder
O Jan 17, 1964	H-54704	1225.00 (OMSF)	A&M College final payment

Of these funds, the total FY 1964 OSSA expended or committed funds are \$29,617. Commitment of the approximately \$40,000 remaining will depend on the successful orbiting of S-66 at some future date.

4. Major Accomplishments. See Technical Status.
5. Problems. No problems are reported at this time.
6. Future Plans. See technical status.
7. Illustrations. Attachment I (comparison of winter Ionosphere Electron contents observed at Boulder, Stanford, Urbana, and Huntsville). Figures 4 and 5.

## ATTACHMENT I

### COMPARISON OF WINTER IONOSPHERE ELECTRON CONTENTS OBSERVED AT BOULDER, STANFORD, URBANA, AND HUNTSVILLE

E. A. Mechtly and F. A. Rodrigue

National Aeronautics and Space Administration  
Huntsville, Alabama

## ABSTRACT

The electron content of the ionosphere above Huntsville is compared with the electron content above Boulder, Stanford, and Urbana for October, November, and December of 1959. The Huntsville results confirm the Boulder and Stanford results that the 1959 early winter mid-latitude diurnal change of electron content ranged from  $10^{16} \text{ m}^{-2}$  at night to  $5 \times 10^{17} \text{ m}^{-2}$  at midday with gradients of about

$10^{17} \text{ m}^{-2} \text{ hour}^{-1}$  preceeding and following midday. The Huntsville results are derived from the Faraday polarization fades of 20 mc/s signals received from Satellite 1959 Iota 1 (Explorer VII). The method of analysis, and errors resulting from gradients of electron content and from the chosen representation of the geomagnetic field are discussed.

## INTRODUCTION

Lawrence, Posakony, Garriott, and Hall (1963) have published curves showing mid-latitude diurnal and seasonal variations of ionospheric electron content. Their work is based on observations of polarization fades of primarily 20 mc/s signals from Sputnik III as it passed over Boulder, Colorado, and over Stanford, California. A two mode ray-tracing analysis described by Lawrence and Posakony (1961) was applied to both the Boulder and Stanford observations. The passages over Boulder and Stanford showed no appreciable systematic differences and the results were combined.

In an earlier paper, Yeh and Swenson (1961) plot electron contents over Urbana, Illinois calculated from 20 mc/s and some 40 mc/s polarization fades of signals also from Sputnik III.

Electron contents presented here for Huntsville are derived from polarization fades of 20 mc/s signals from a different satellite, 1959 Iota 1 (Explorer VII), but for a coincident time period, October, November, and December of 1959.

The Boulder, Stanford, and Huntsville results are in good agreement for this time period. They show a diurnal change of electron content ranging from  $10^{16} \text{ m}^{-2}$  at night to  $5 \times 10^{17} \text{ m}^{-2}$  at midday with gradients preceeding and following midday of about  $10^{17} \text{ m}^{-2} \text{ hour}^{-1}$  in magnitude. The values of electron content computed for Urbana are systematically larger than those for Boulder, Stanford, and Huntsville for the same time period.

In the following paragraphs, the method of analysis applied to Huntsville observations is described. Errors resulting from gradients of electron content, from the chosen representation of the geomagnetic field, and from other approximations are discussed. Electron contents for Boulder, Stanford, Urbana, and Huntsville are plotted on the same graph for ease of comparison.

## CHARACTERISTICS OF EXPLORER VII

Explorer VII was launched into an orbit of 553 km perigee, 1090 km apogee, and 50.3° inclination with the earth's equatorial plane on 13 October 1959. Explorer VII radiated circularly polarized 20 mc/s telemetry signals in the direction of its well stabilized spin axis. Radiation in most other directions was sufficiently quasilinear to reveal Faraday polarization fading patterns in signals received by linearly polarized antennas. However, these patterns were frequently obscured by scintillation caused by ionospheric irregularities and sometimes, by electromagnetic (lightning) storms. Imperfect circular polarization about the spin axis causes a 10.6 c/s amplitude modulation of the observed signal strength. This modulation introduced as persistent but small ambiguity in the identification of the times of polarization fades. Additional characteristics of Explorer VII are given in the Transactions of the American Geophysical Union (1959).

## METHOD OF ANALYSIS

The spin stabilization of Explorer VII made changes in the relative angular positions of the satellite transmitting antenna and the ground based receiving antenna negligible over the time interval between any two adjacent polarization fades. Thus, one is confident that the number of rotations of the plane of polarization along the ray path between the satellite and observer increased or decreased by one-half between any two adjacent fades. This rather precise relationship may be written as

$$\Omega_i - \Omega_j = \frac{1}{2}, \quad (1)$$

where  $\Omega_i$  and  $\Omega_j$  are the unknown numbers of rotations along the ray paths corresponding to the two adjacent polarization fades  $i$  and  $j$ .

The present method of analysis relates the number of polarization rotations,  $\Omega$ , to the ionosphere electron content,  $I$  (electron number/meter<sup>2</sup>) in an equivalent vertical column to the height of the satellite, by the equation

$$\Omega = \frac{C_1}{f^2} (B \cos \Theta \sec X) I, \quad (2)$$

where  $C_1 = 3764$

$f$  = wave frequency (sec<sup>-1</sup>)

$B$  = geomagnetic flux density (tesla)

$\Theta$  = angle between field vector and ray path direction

$X$  = zenith angle.

The approximations required for the derivation of this equation and the limits of their validity are discussed by Browne et al. (1956), and Garriott (1960).

A critical assumption is now made. The ray paths  $i$  and  $j$  are assumed to be sufficiently close together with respect to the distribution of free electrons in the ionosphere that

$$I_i = I_j = I. \quad (3)$$

This assumption states that the electron contents along ray paths  $i$  and  $j$  corresponding to adjacent fades are equal, but it does permit  $I$  to take on different values for other adjacent pairs of ray paths. Possible errors in calculated values of  $I$ , arising from this assumption, are discussed later.

Equations 1, 2, and 3 are now written together as

$$I = 1.328 \times 10^{-4} f^2 \frac{1}{[(B \cos \Theta \sec X)_i - (B \cos \Theta \sec X)_j]} \quad (4)$$

A computer program for calculating ionosphere electron contents is built around Equation 4. The position of the satellite is calculated from the orbital elements published by the Smithsonian Institution Astrophysical Observatory in a series of reports on "Research in Space Science" (1960).

The height of maximum ionization is assumed to be

$$h_m = 337.5 - 37.5 \cos [(360/24) (\text{CST} - 13)] \quad (5)$$

in km above a spherical earth of radius 6378388 meters. This function ranges from 300 km at 13<sup>h</sup> Central Standard Time to 375 km at 1<sup>h</sup> C. S. T.

A point on the ray path at the height  $h_m$  is designated as the ionosphere point. The angle of the local vertical at the ionosphere point with the ray path is the zenith angle,  $X$ , of Equations 2, and 4. The geomagnetic flux density,  $B$ , and the angle,  $\Theta$ , of the field vector with the ray path are also calculated at the ionosphere point.

The geomagnetic field is represented by the spherical harmonic expansion based on the 48 Gaussian coefficients published by Finch and Leaton (1957) for epoch 1955.0.

An ionosphere time, IT, is associated with each calculated value of electron content, I. This time is defined by the equation

$$IT = [ (T_i - T_j)/2 ] - [ 24/360 ] \lambda, \quad (6)$$

where  $T_i$  and  $T_j$  are the Greenwich Mean Times at which adjacent fades i and j are observed, and  $\lambda$  is the west longitude of the ionosphere point.

### ERROR SOURCES

Garriott (1960) has demonstrated that path separation of the two magneto-ionic modes is negligible for zenith angles less than about 40 degrees. To reduce errors resulting from path splitting and refraction, only those fades observed when the satellite zenith angle was 40 degrees or less are considered in the present analysis.

The quasi-longitudinal approximation of the Appleton-Hartree equation, upon which the derivation of Equation 2 is based, fails for  $\Theta > 85^\circ$ . However, the restriction on the zenith angle excludes this possibility at the latitude of Huntsville.

At a wave frequency of 20 mc/s, the quantity I of Equation 2, retaining only the first two terms of the expanded QL equations, is

$$I = \int (N + 10^{-13} N^2) dh, \quad (7)$$

where the limits of the integral are zero, and the height of the satellite. A mid-day maximum electron density of  $N = 10^{12} \text{ m}^{-3}$  means that I is about 10 per cent larger than the electron content,  $\int N dh$ . Fortunately, the electron density is less than  $10^{12} \text{ m}^{-3}$  at most places and times so that I may be taken as the electron content with an error usually much less than 10 per cent. A knowledge of  $N_{\text{max}}$  permits a quantitative estimate of the contribution of the  $N^2$  and higher order terms, which may be used to correct values of I. Unfortunately, no independent measurements of  $N_{\text{max}}$  are available. The effect of variations in the assumed value of  $h_m$  on the calculated values of I is discussed later.

The vertical motion of a satellite introduces a change of electron content measured to the height of the satellite. For an exaggerated worst case of 6000 meters height-change of Explorer VII between fades, and an excessively large assumed electron density of say  $10^{11} \text{ m}^{-3}$  at about 700 km, the electron content change is only  $6 \times 10^{14} \text{ m}^{-2}$ . This change is negligible relative to the errors from other sources.

The most serious source of error is gradients of electron content. The assumption expressed by Equation 3 is usually not satisfied. It is easily shown that the fractional deviation,  $D$ , of calculated values of  $I$ , based on Equation 4, from  $I'_i$  which has a linear gradient such that

$$I'_j = (1 + \epsilon) I'_i$$

is

$$D = 2 \epsilon \Omega, \quad (8)$$

where  $\Omega$  is positive for an increasing number of polarization rotations. Both  $\epsilon$  and  $\Omega$  are consistently positive for southbound satellite passages and negative for northbound passages so that  $D$  is always positive, indicating a consistent overestimate of electron content when gradients are present. For example, Explorer VII moving at perigee speed of 7.7 km/s so that the ionosphere point moves about 10 km between fades separated by 2.5 seconds. A realistic electron content gradient of 5 per cent 100 km and 50 polarization rotations would then produce a calculated value of electron content 50 per cent too large! This serious difficulty with gradients of electron content is a problem common to all methods of separate analysis of either polarization or Doppler data, and probably can be treated adequately only when simultaneous observations of the anisotropic and dispersive properties of the ionosphere are available. The ionosphere beacon type of satellite (e.g. S-66) is, of course, designed to provide such simultaneous observations.

## COMPARISON OF ELECTRON CONTENTS

Figure 4 shows electron content and its diurnal variation as determined from observations at Boulder, Standord, Urbana, and Huntsville for Oct., Nov., and Dec. of 1959. The solid curve represents the work of Lawrence, Posakony, Garriott, and Hall (1963); and the dashed curve, the work of Yeh and Swenson (1961). The black dots are values of electron content calculated by the method of analysis described above, corresponding to the closest approaches of Explorer VII to the Huntsville Station, and uncorrected for probable errors. The Huntsville results include all available Explorer VII observations which were made in the specified time period with the zenith angle always less than 40 degrees and under magnetically undisturbed conditions.

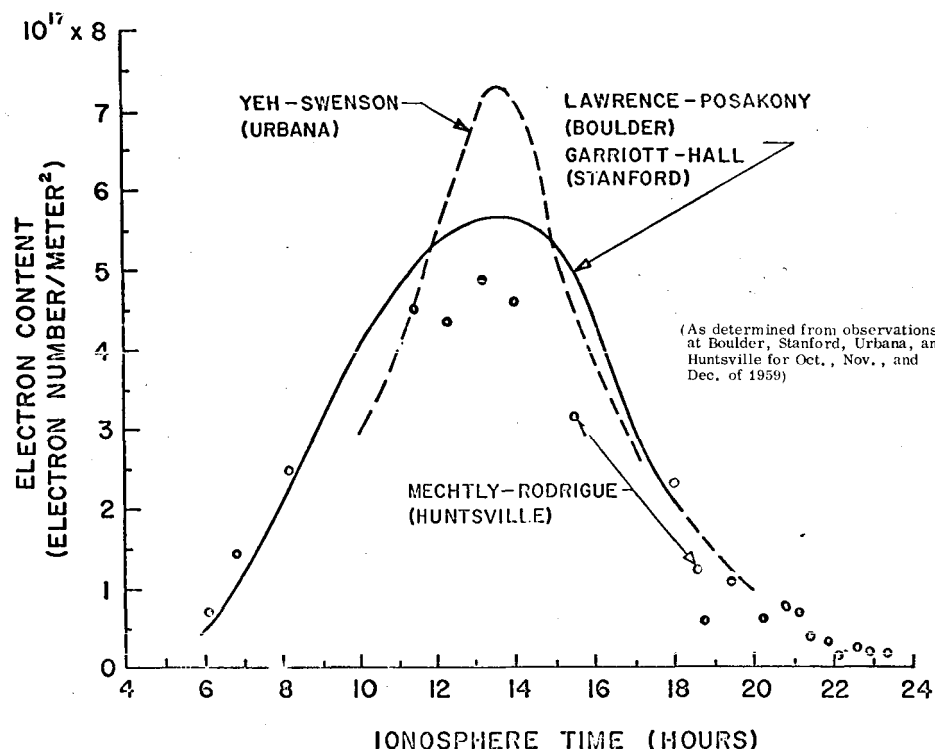


FIGURE 4. COMPARISON OF ELECTRON CONTENT DIURNAL VARIATIONS

The latitude of Urbana is about 40 degrees N.; Stanford, 37 degrees; and Huntsville, 35 degrees. One might hastily conclude that the different electron contents observed at noon are a real variation with latitude. However, Boulder is at the same latitude as Urbana, and the Boulder and Stanford investigators found no systematic differences in their calculated electron contents. Furthermore, Explorer VII passes consistently show decreasing electron content with increasing latitude of the ionosphere point. This fact is illustrated in Figure 5 which shows sequences of computed values of electron content for typical passes of Explorer VII. The pass of October 22 was south to north, and the pass of November 14, north to south. Although increasing electron contents with decreasing latitude of the ionosphere point have been observed consistently, they are not sufficiently regular to permit plots of contours of constant electron content in a latitude-time plane.

The different electron contents of Figure 4 at noon can be explained, at least in part, by difference in the methods of analysis. The ray tracing method of Lawrence and Posakony (1961) assumes a model of electron density as a function of height which is ultimately integrated to infinity to give the electron content of the total ionosphere. The present method of analysis evaluates the electron content only to the height of the satellite. The point of Figure 4 at 12<sup>h</sup> 20<sup>m</sup>, for example, does not include the portion of the ionosphere above 579 km (the height of the satellite at the time).



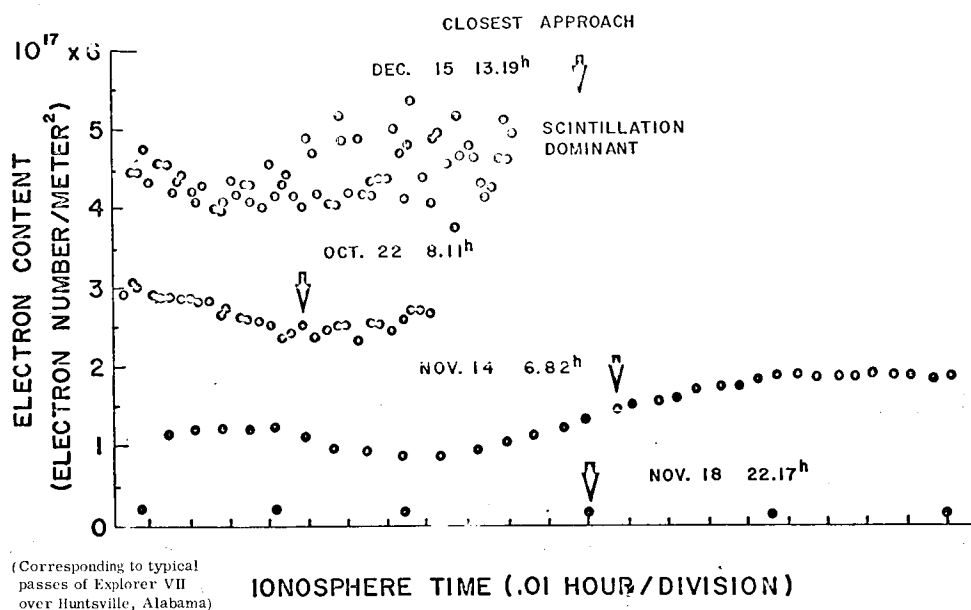


FIGURE 5. APPARENT GRADIENTS AND IRREGULARITIES OF IONOSPHERE ELECTRON CONTENT

Closest approaches of Explorer VII to the Huntsville Station are marked by arrows in Figure 5. The November 18th sequence at about 22<sup>h</sup> is typical of the nighttime passes. The widely spaced points reflected the relatively slow rate of polarization fading. Changes of fluctuations in the calculated values are comparatively small, indicating the absence of electron content gradients, irregularities, and analysis errors. The December 15th pattern for 13<sup>h</sup> shows considerable scatter. This is due in part to scintillation which eventually completely obscures the polarization fading. However, some of the scatter can be attributed to poorly defined fades resulting from the superposition of the 10.6 c/s satellite spin modulation of the transmitted signals. On November 14th Explorer VII passed from north west to south west into the rising sun, making its closest approach to the Huntsville Station at an ionosphere time of 6.82<sup>h</sup>. This pass shows a large apparent horizontal gradient in Figure 5, and one can expect a large error in the calculated values of electron content. First of all, the morning gradient of Figure 4 is about  $10^{17} \text{ m}^{-2} \text{ hour}^{-1}$ . The apparent gradient of the 6.82<sup>h</sup> pass of Figure 5 is about  $3 \times 10^{17} \text{ m}^{-2} \text{ hour}^{-1}$ , which is not impossibly large even if accepted without correction. This gradient corresponds to an increasing electron content of about 2 per cent between fades. The calculated number of polarization rotations was of the order of 40 at closest approach, and increasing. For these conditions, Equation 8 predicts an 80 per cent overestimate of electron content. However, the early and late portions of the pass display nearly constant values of  $I$  which suggest the absence of large gradients, comparatively accurate values of  $I$ , and an overall increase of electron content of only 27 per cent. Thus, Equation 8 appears to predict an excessively large overestimate of  $I$ .

## VARIATION OF ELECTRON CONTENT WITH $h_m$

The centroid of ionization is known to be somewhat above the height of maximum ionization and it can be argued that the height of the centroid is the better choice of locations for the ionosphere point at which to evaluate the geomagnetic field. This question is examined by numerical calculations of the effect of variations in the assumed location of the ionosphere point on calculated values of electron content. For this study, 40 passes of Explorer VII observed over the time period from October of 1959 to October 1960, and all having zenith angles less than 40 per cent were chosen. Values of  $I$  were computed for values of  $h_m - 50$  km,  $h_m + 50$  km and  $h_m + 100$  km;  $h_m$  defined by Equation 5. These values of  $I$  were compared with those calculated for  $h_m + 0$  km. The results of these variation calculations are given in Table 1. It is evident from the deviations of Table 1 that a precise measurement or estimate of the height of maximum ionization or centroid of ionization is unnecessary. Errors resulting from unknown gradients of  $I$  are considerably more critical.

TABLE 1. DEVIATION OF CALCULATED IONOSPHERE ELECTRON CONTENT WITH VARIATIONS IN THE ASSUMED HEIGHT OF MAXIMUM IONIZATION.

		Variation of $h_m$		
		- 50 km	+ 50 km	+ 100 km
Per cent Deviation of $I$	Minimum	- 2.3	+ 2.4	+ 4.8
	Standard	- 4.3	+ 4.5	+ 9.7
	Maximum	- 7.0	+ 7.6	+ 20.0

## CONCLUSIONS

We conclude that the solid curve of Lawrence, Posakony, Garriott, and Hall in Figure 1 of approximately 1000 per cent diurnal variation of the mid-latitude total ionosphere electron content for October, November, and December

1959 is a good representation for Huntsville as well as for Boulder and Standard. The good agreement and estimates of errors lead one to believe that the present comparatively simple method of analysis, which does not require ray tracing procedures, is capable of giving results accurate within about 2 per cent or 3 per cent of the diurnal variation. The most serious difficulty with the present method is the problem of errors resulting from unknown gradients of electron content. It is expected that the opportunity to observe simultaneously both the anisotropic and the dispersive properties of the ionosphere by means of satellites designed as ionosphere beacons shall provide solutions to this problem.

#### ACKNOWLEDGEMENTS

The Explorer VII data upon which this paper is based was recorded by J. G. Gregory, W. H. Edens, G. M. Kozub, T. B. Barnes, and C. R. Glass. Much of the work of digitizing the times of polarization fades was done by part-time student employees of the Marshall Space Flight Center.

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Transactions American Geophysical Union, IGY Satellite 1959 Iota, 40 (4), 401, 1959.

## ATTACHMENT II

### ALABAMA AGRICULTURAL AND MECHANICAL COLLEGE Normal, Alabama

#### DATA ANALYSIS FOR IONOSPHERIC STUDY

by

William L. Kimber

The Alabama Agricultural and Mechanical College, Normal, Alabama, entered into contract with the National Aeronautics and Space Administration (NASA) June 10, 1963, to reduce and analyze scientific data derived from Satellite 1959 Iota (Explorer VII) and Polar Orbit Ionosphere Beacon Satellite (S-66).

Specifically, the contractor (Alabama Agricultural and Mechanical College) agreed to analyze the National Bureau of Standards WWV timing markers and accurately measure the times of polarization fades for the signal strengths by reference to WWV timing markers.

On or about June 10, 1963, Alabama Agricultural and Mechanical College received from Dr. Eugene A. Mechtly, six-hundred eighty-one (681) data graphs, one-hundred three (103) tapes and seven (7) logs covering activities of Satellite 1959 Iota. The Beacon Satellite (S-66) has not yet been launched into orbit by NASA, and has, therefore, produced no data.

The times of polarization fades of signal strengths of 1959 Iota were computed by reference timing markers. Of the 681 graphs upon which computations were made, 263 were completely clear and readable. The time fades were calculated fully; 133 were partially readable and calculated as far as possible; 285 were not readable and registered only as noises. The data sheets have been separated into the appropriate years, months, days, minutes, seconds, and tenths of second.

The instrument used to analyze the data was the Paragon Metric Triangular scale, 30 cm. These scales have six different scale units ranging from divisions of 0.05 cm to 0.0125 cm (0.05, 0.03, 0.02, 0.01, 0.025, and 0.0125 centimeters). The scales were adequate and accurate enough to provide measurements on the fluctuation of time spaces. The measurements of time were precise to tenths of a second.

Our experience has shown that the Paragon Metric Scales are entirely satisfactory for computations of this nature.

These data were computed by students of Alabama Agricultural and Mechanical College under the supervision of William L. Kimber.

All materials received and all data computed are ready for pick-up by NASA.

William L. Kimber

### SECTION III. METEOROLOGICAL PROGRAMS

#### METEOROLOGICAL SYSTEMS RESEARCH

##### A. HIGH ALTITUDE (70-90 km) WIND SHEAR MEASURING PROGRAM

Submitted by  
(Technical Supervisor)

Robert E. Turner  
R-AERO-YA, 876-2767

1. Project Data

Contract number: NAS8-5175, 11-62

Completion date: 8-64

Contractor: Rocket Power, Inc.  
Mesa, Arizona

2. Purpose of Project. The purpose is to obtain statistical wind and wind shear data for analysis of atmospheric conditions at Cape Kennedy, Florida; to acquire data for use in large space vehicle design studies, and assist in evaluation of specific vehicle flight tests.

3. Technical Status. Fifteen Hopi-Dart rockets with chaff payload were procured from Rocket Power, Inc. A minimum of 80 per cent of these are to perform according to specifications to an altitude of 90 - 95 kilometers. During this reporting period 14 flights were made, in which 6 met specifications. Six additional successful flights are required to meet the contract agreements. The test program was moved from Wallops Island, Va. to Tonapah, Nevada, Test Range. Initial operational firings at Cape Kennedy are expected in early 1964.

4. Major Accomplishments. The test program for acceptance of Hopi-Dart rockets to be fired from Cape Kennedy has been completed.

5. Problems. The problems encountered involving aerodynamic heating of the chaff payload have been solved. A thrust misalignment was encountered on one test which caused the rocket to fail. This has also been corrected in future rocket deliveries.

6. Future Plans. Action will be taken to obtain approximately 50 additional Hopi-Dart rockets for use at Cape Kennedy, Florida. These will be fired at the rate of one per week for a year's period, to collect a statistical sample of data for design criteria studies.

7. Illustrations. None.

## SECTION IV. ELECTRICAL PROPULSION

### A. CALCULATIONS OF WAVE FUNCTIONS BY HARTREE METHOD

Submitted by  
(Technical Supervisor)

I. Dalins  
R-RP-N, 876-1891 and 536-1311

1. Project Data

Contract number: NAS8-880, 1-23-61

Completion date: 12-63

Contractor: University of Alabama  
Physics Department  
Tuscaloosa, Alabama

2. Purpose of Project. Calculate electronic wave functions and scattering cross sections of certain, predominantly, cesium atoms using modern computation techniques, especially the large computers. No change from previously stated objective.

3. Technical Status. Contract expired. The proposed work was completed.

4. Major Accomplishments. A general review report was written covering the problems encountered and possible approaches in solving them. The latest results were published in Physical Review, Vol. 130, April 15, 1963. This is indicative of the scientific quality of this work.

5. Problems. No administrative problems were encountered, except for some time required for commuting between Tuscaloosa and MSFC to use the large MSFC computational equipment. Technically, one of the recent and most taxing problems encountered was the effort required in making a selection of polarization potential. Numerous calculations were made in order to arrive at an acceptable functional form. The potential selected suits the most recent experimental data.



6. Future Plans. It is planned to continue with this type of theoretical physics research to encompass other atoms, especially from the alkali group. For the time being, the costs of these studies will be covered by the remaining funds of contract NAS8-1503. A new contract has been initiated to continue with this line of work with special emphasis on inelastic scattering problems.

7. Illustrations. None other than the references made on publications mentioned earlier.

## B. COMPUTER SOLUTION OF THE VLASOV EQUATIONS

Submitted by  
(Technical Supervisor)

Lawrence H. Wood

### 1. Project Data

Contract number: NAS8-5214

Contractor: General Electric Company,  
Evandale, Ohio

2. Purpose of Project. The purpose of this project is the investigation of charged particle dynamics in the presence of space charge by the solution of the Boltzmann-D'Alembert equations using an IBM 7090 digital computer.

### 3. Technical Status. Status is as follows:

a. A computer program has been developed which will permit solutions of a wide range of cylindrical plasma diode potential distribution problems. This program is currently being used at Marshall to solve problems and should be fully developed in the near future.

b. A computer program is being developed which will permit solutions to planar plasma diode potential distribution problems.

c. Numerical investigation is being made of different classes of planar and cylindrical plasma probe potential and voltage-current-characteristic problems in order to develop computer programs which will permit solutions of these problems. At the present time, difficulty is being encountered in "mapping" probe potential curve solutions into a neutral plasma.

4. Major Accomplishments. Accomplishments are:

a. A computer program which permits solutions of plasma diode potential distribution problems is nearly complete.

b. Some potential distribution curves for planar and cylindrical plasma diodes have been obtained. These results rigorously include thermal effects and do not appear to have been obtained anywhere previously.

5. Problems. None.

6. Future Plans. Plans are:

a. The cylindrical diode program development will be continued and written up for general use.

b. Various classes of solutions to cylindrical and planar diode problems will be investigated. These calculations will be combined with theoretical results being obtained at Marshall Space Flight Center and submitted to a scientific journal for publication.

c. Investigation of the plasma probes will be continued.

7. Illustrations: None.

C. STUDIES FOR THE DETERMINATION OF THE VAPOR PRESSURE OF CESIUM

Submitted by  
(Technical Supervisor)

Dr. Spencer G. Frary

1. Project Data

Contract number: NAS8-2624, 2-16-62

Completion date: 2-15-63  
Extended to 8-15-63

Contractor: School of Chemistry  
University of Alabama  
Tuscaloosa, Alabama

2. Purpose of Project. To determine, by analytical and experimental studies, the vapor pressure of cesium over the approximate temperature range of 0 to 600° C.

3. Technical Status. Work on this project has been completed and a final report submitted.

4. Major Accomplishments. The vapor pressure of cesium was determined between 150 and 215° C.

5. Problems. Delays in obtaining equipment and lack of funds for further studies prevented determination of vapor pressures above 215° C.

6. Future Plans. None.

7. Illustrations. None.

## APPENDIX

### THE TECHNICAL SUPERVISORS

Mr. Ron G. Crawford, Structures Division, P&VE, received his BS Degree in Civil Engineering from Texas A&M in January, 1954, and his MS Degree in Structural Engineering from SMU in January, 1962. He joined the Stress Department of Chance Vought Aircraft in January, 1954, and was responsible for the structural integrity of the prototype models of the highly successful F8U-1. In 1956 he was assigned responsibility for a load analysis of the F101B forward fuselage. He transferred to Ling-Temco-Vought in 1957, where he was responsible for the design structural integrity of major assemblies of the B-52G, and the stress analysis report for the aft fuselage. He directed major structural test programs on the T T-1 trainer and Corvus missile. He joined MSFC in January 1961, where his duties have included division coordination of the development of the Lunar Logistics Vehicle and the Multi-Mission Module.

Dr. Ilmars Dalins, Nuclear and Ion Physics Branch, Research Projects Laboratory, graduated with a BA degree from Texas Lutheran College, a MA degree from the University of Texas, and a Ph.D from the University of Cincinnati. His professional experiences consist of studies of radome materials while at North American Aviation, Inc., and rocket engine instability while at General Electric Co. Since 1957, Dr. Dalins has been engaged in research in physical electronics problems of ion propulsion, especially specializing in problems connected with surface ionization. At present, he is engaged in theoretical and experimental studies of surface physics problems as connected to outer space technology. He is the technical supervisor for several research contracts. Dr. Dalins has written and presented two papers on Ion Rockets to the ARS.

Mr. Keith E. Demorest of the Materials Division, Propulsion and Vehicle Engineering Laboratory, was graduated from the University of Omaha in 1951 with a BA degree in Physics.

Prior to joining NASA, Mr. Demorest was engaged in bearing and lubrication work with the Research Laboratory of Caterpillar Tractor Company. Presently he is chief of the Lubrication and Surface Physics Unit of the Experimental Physics Section where he is currently involved in space lubrication studies.

The following research contracts are under the technical supervision of Mr. Demorest:

- a. NAS8-1540, "Research on Bearings for Use in High Vacuum."
- b. NAS8-11066, "An Investigation of Adhesion and Cohesion in Vacuum."
- c. NAS8-11537, "Research and Development of Materials for Use as Lubricants in A Liquid Hydrogen Environment."

Dr. Spencer G. Frary, Ion and Nuclear Physics Branch, Research Projects Laboratory, is a graduate of Case Institute of Technology (BS chemical engineering, 1926). He received his Ph. D from Western Reserve University in inorganic chemistry in 1936. He was with the TVA until 1942 at which time he transferred to the Chemical Corps at Redstone Arsenal, remaining there until 1947. He taught chemistry at Howard College in Birmingham, Alabama (1947-1949) and at Jacksonville (Alabama) State College (1949-1951). He returned to the Ordnance Corps in 1951, working in Solid Propellant Rockets, and since 1956, on upper-atmospheric chemistry and physics. He became associated with NASA in 1960. Dr. Frary has participated in the observational programs of Gas Light and High Water. He is at present embarking on a study of physico-chemical reactions in the upper atmosphere.

Mr. Raymond Gause of the Materials Division of the Propulsion and Vehicle Engineering Laboratory was graduated from Southwestern Oklahoma State College in 1957 with a BS degree in physics and mathematics and has completed two years of graduate work toward the MS degree in Engineering Mechanics at the University of Alabama, Huntsville Center.

Following his graduation, Mr. Gause was employed until 1958 by the Army Ballistic Missile Agency as a Research Engineer. From 1958 to 1961, he was associated with the White Sands Missile Range as a Radiation Effects Physicist. In 1961, he joined the NASA and is presently chief of the Radiation and Environmental Physics Unit of the Experimental Physics Section. Currently, his work pertains to the evaluation of the effects of the various parameters of the space environment on materials.

The following contracts are under the technical supervision of Mr. Gause:

- a. NAS8-2450, "Investigation of the Combined Effects of Radiation and Vacuum on Engineering Materials."
- b. NAS8-11075, "Development of Improved Thermoelectric Materials for Spacecraft Applications."

Mr. Harvard H. Kranzlein of the Materials Division of the Propulsion and Vehicle Engineering Laboratory was graduated from the Polytechnic Institute of Brooklyn and Cornell University. He received his B. Met. E. degree from the Polytechnic Institute of Brooklyn in 1955 and began work with E.I. duPont de Nemours and Company, at the Atomic Energy Commission's Savannah River Laboratory. Assignments with the Physical Metallurgy group included studies of aluminum, stainless steel, zirconium, and uranium. In 1962 he received a MS degree in metallurgy from Cornell and began work at MSFC. Assignments with the Alloy Development Unit include investigation of solidification rate effects in 5000 series aluminum and examination of the structures of welded 2000 series alloys.

The following research contract is under the technical supervision of Mr. Kranzlein:

NAS8-11048, "Investigation of Foamed Metals for Application on Space Capsules."

Mr. Eugene C. McKannan of the Materials Division of the Propulsion and Vehicle Engineering Laboratory was graduated from West Chester State College in Pennsylvania in 1949 with a BS degree in physics and mathematics, and subsequently attended the Universities of Delaware and Alabama for graduate courses.

Following his graduation, he was associated with the U. S. Army Ordnance Guided Missile Center, Redstone, until 1952, and until 1961 he was employed by the E. I. duPont de Nemours & Co., Inc. where he was involved in polymer physics, rheology, and electrical insulation developments. Presently, he is chief of the Experimental Physics Section of the Engineering Physics Branch, Materials Division and has been doing research on electrical contracts, insulation, and dry film lubrication in the space environment. He has published papers in the Journal of Applied Physics, Wire and Wire Products, and the American Society of Lubrication Engineers Transactions.

The following research contracts under the technical supervision of Mr. McKannan:

- a. NAS8-2442, "Low Temperature Coatings for Electrical Conductors."
- b. NAS8-5253, "Behavior of Dielectric Materials at High Field Strengths in a High Vacuum Environment."
- c. NAS8-11026, "Dielectric Windows for Spacecraft Antennae."

Dr. Eugene A. Mechtly is a native of Pennsylvania. He received his BS in Physics from Western Maryland College, Westminster, Maryland, 1952. He attended the University of Innsbruck, Austria, 1952-1953, on a Fulbright Scholarship. His military service includes: assignment to Army Ordnance Missile Laboratories, Guided Missile Development Division, Huntsville, Alabama, 1954-1955; helped develop Program Device tape recorder for Redstone Missile.

Civilian Employee in Guidance and Control Laboratory of the Guided Missile Development Division, 1956. MS in Physics, Pennsylvania State University, 1958, on leave from the Army Ballistic Missile Agency. Participated in launching of Explorer I Satellite, 1958. Ph.D in Physics, Pennsylvania State University, 1962; thesis research on Measurements of Ionospheric Electron Density by means of instruments carried into the upper atmosphere during development flights of the Jupiter Missile.

Currently working on problems of the physics of our Solar System, specializing in Radio Physics, at the Research Projects Laboratory of the Marshall Space Flight Center.

Member: American Geophysical Union  
Sigma X  
American Physical Society (S.E. Section)

Mr. John T. Schell of the Non-Metallic Materials Branch, Materials Division, Propulsion and Vehicle Engineering Laboratory was graduated from Auburn University in 1943 with a BS Degree in Chemical Engineering. He has done work toward an MS degree in Chemistry at the Huntsville Center of the University of Alabama. Subsequent to his graduation, he was employed by the Dayton Rubber Company for fifteen years during which time he attained the position of Technical Superintendant of the Atlanta, Georgia plant.

Presently, he is Chief of the Rubber and Plastics Technology Section. His duties include responsibility for research and development in the field of rubber and plastics technology as well as studies of reinforced and non-reinforced materials.

The following research contracts are under the technical supervision of Mr. Schell:

1. NAS8-5352, "Development of Vulcanizable Elastomers Suitable for Use in Contact With Liquid Oxygen."
2. NAS8-5499, "Development of Heat Sterilization Potting Compound."

Mr. Robert E. Turner, Aero-Astrophysics Office, Aero-Astrodynamic Laboratory, is a graduate of the University of Alabama. He received his BS degree in engineering from Alabama in 1960. Mr. Turner worked for the Army at Redstone for eight years in Instrumentation. In 1960 he transferred to MSFC and was assigned to Aero-Astrophysics Office to set up and operate an atmospheric measuring station at MSFC and MTO. Research contracts under his supervision include NAS8-5246.

Mr. Lawrence H. Wood, Ion and Nuclear Physics Branch, Research Projects Laboratory, is a graduate of the University of Maine, where he received a BS degree in electrical engineering. He is currently pursuing a MS in physics at the University of Alabama. Prior to a three-year tour in the Army, he was associated for a year with the Aearfott Company of Little Falls, New Jersey, where he designed alignment loops for stable platforms and performed other related tasks. Mr. Wood served his Army tour at the Ordnance Guided Missile School. Research contracts under his supervision include contract NAS8-623, "Computer Solution of the Vlasov Equations."



SEMI-ANNUAL PROGRESS REPORT

PART III

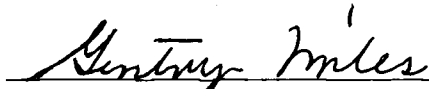
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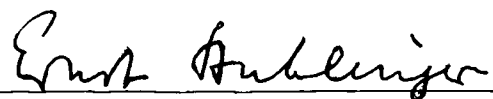
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(July 1, 1963 to January 1, 1964)

Harry J. Coons, Jr.

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